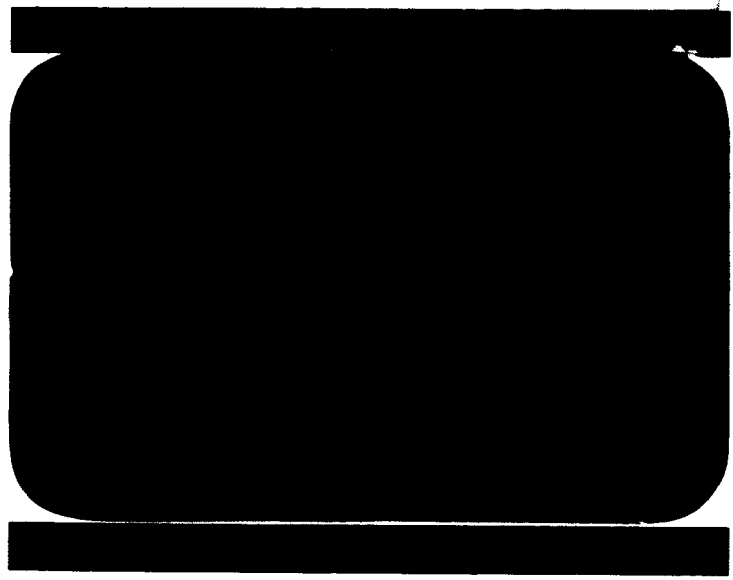


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GENERAL DYNAMICS
Convair Division



EFFECTS OF SHEET THICKNESS ON THE
MECHANICAL PROPERTIES OF TYPE 301 EFH
STAINLESS STEEL AT CRYOGENIC TEMPERATURES.

MRG-195

November 30, 1960

Prepared by: J.L. Christian
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GENERAL DYNAMICS/CONVAIR

CONVAIR ASTRONAUTICS



REPORT MRG-195

PAGE 1

30 November 1960

SUBJECT: "Effects of Sheet Thickness on the Mechanical Properties of Type 301 EFH Stainless Steel at Cryogenic Temperatures."

ABSTRACT: Mechanical properties were determined at room and cryogenic temperatures on Type 301 EFH stainless steel sheet in the following thicknesses: 0.013, 0.023, 0.032, 0.060, 0.080 and 0.100 inches. This report shows the effect of sheet thickness on tensile strength, 0.2% yield strength, elongation, notched tensile strength, notched/unnotched tensile ratio, heliarc butt welded tensile strength and elongation, and joint efficiency at 75, -100, -320, and -423°F. The results of these data are presented and their significance discussed.

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30 November 1960

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FROM: Materials Research Group, 592-1

SUBJECT: Effects of Sheet Thickness on the Mechanical Properties of Type 301 EFH Stainless Steel at Cryogenic Temperatures.

Mechanical properties were determined on 301 EFH stainless steel sheet in several thicknesses which ranged from 0.013 to 0.100 inches. The mechanical properties determined were F_{tu} , F_{ty} , ϵ_l , notched tensile strength, notched/unnotched tensile ratio, weld F_{tu} and ϵ_l , and joint efficiency. Data were obtained at +78, -100, -320 and -423°F. It is the purpose of this report to present the data in such a manner as to show the effects of thickness on the mechanical properties of 60% cold rolled 301 stainless steel at room and cryogenic temperatures.

Table I gives the history and chemical analysis of materials used in this investigation. Although all of the sheet materials were not from the same heat (which would be preferable for this type of study), the chemistries of the individual heats are quite similar. Note also that the 0.060, 0.080 and 0.100 inch material are from one heat. Heliarc butt weld schedules are presented in Table II. Mechanical property data are plotted versus sheet thickness in Figures 1 through 8. The mechanical property data were obtained parallel to the direction of rolling (longitudinal) and normal to the direction of rolling (transverse) at 78°, -100°, -320° and -423°F.

Figure 1 is a plot of 0.2% yield strength (F_{ty}) versus sheet thickness. Although all the materials tested in this program were cold rolled to about 60% reduction, the 0.013, 0.023 and 0.032 inch gauge materials have higher yield strengths at room temperature than the 0.060, 0.080 and 0.100 inch gauge materials. This effect is even more noticeable at -320 and -423°F. At each temperature the yield strengths of specimens obtained transverse to the direction of rolling are less than those obtained longitudinal to the direction of rolling. However, the trend of the data for both directions is the same which indicates that the sheet thickness affects the yield strength irrespective of rolling direction. In general there appears to be a definite effect of sheet thickness on the yield strength of 301 S.S., which is shown by a decrease in F_{ty} with increase in thickness, particularly at -423°F. A possible explanation of this data is based upon surface yielding (yield strengths are calculated from the stress-strain curves obtained from extensometers which act on the surfaces of the tensile specimen). This would explain the lower yield strengths obtained for the thicker gauge material since 0.004 inches of extension over a 2 inch gauge length (0.2% offset) could be obtained at a lower load on the thicker material than the thin gauge material if there is preferential yielding at the surface.

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Figure 2 is a plot of tensile strength (F_{tu}) versus sheet thickness. There appears to be very little effect of thickness on the tensile strength of 301 XFH stainless steel, with the exception of a possible decrease in transverse F_{tu} with increase in thickness at the extreme sub-zero temperatures.

Figure 3 shows the effect of sheet thickness on elongation of the base metal. Although there is appreciable scatter in the data, there appears to be higher elongation values in the thicker gauge than in the thinner gauge material. This result is to be expected since the heavier gauge material necks down to a greater extent before fracturing than the thinner gauge material thus giving a greater total elongation (which consists of uniform elongation prior to necking plus the elongation developed as a result of local necking).

Figures 4 and 5 show the effect of thickness on notched tensile strength and notched/unnotched tensile ratio. There is little effect of thickness on the notched strengths and notched/unnotched tensile ratios at +78 and -100°F; however, there appears to be a definite decrease of these properties with increase in gauge thickness at -320 and -423°F, particularly for the transverse direction. These data are reversed to what would be expected if the material were fully ductile at the lower temperatures. Higher notched tensile strengths would be expected for the thicker gauges because of the greater amount of triaxial stresses present unless the material became embrittled at the low temperatures. These data indicate that 301 XFH stainless steel becomes more notch sensitive and thus inherently less tough at -320 and -423°F with increase in sheet thickness (over the range 0.013 to 0.100 inches). Note that the greatest embrittlement is apparent in the transverse direction at -423°F (notched/unnotched tensile ratios of 0.55 to 0.75).

Tensile strength and elongation of haliarc butt welded joints are shown as a function of sheet thickness in Figures 6 and 7. There appears to be no effect of thickness on butt weld tensile strength. As expected, there is an increase in elongation of the butt welded joints of the thicker gauges. It is interesting to note the indications of partial embrittlement of the weld at -423°F (tensile strengths and elongations are less than at -320°F). The joint efficiency, as shown in Figure 8, appears to be unaffected by sheet thickness.

Although further research should be conducted to verify these results, it appears that there is an decrease in F_{ty} , increase in elongation, and decrease in notched tensile strength and notched/unnotched tensile ratios (at -320 and -423°F) of cold rolled Type 301 stainless steel with an increase in sheet thickness from 0.013 to 0.100 inches. There appears to be a greater effect at the extreme sub-zero temperatures. It is very important to note that the notch sensitivity and embrittlement of Type 301 stainless steel (60% cold rolled) is affected by an increase in sheet thickness, particularly

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at -320 and -423°F (see Figures 4 and 5). This indicates that the EFH 301 CRES which is marginal in its application for structural use at -423°F due to a partial embrittlement, becomes more severely embrittled at extreme sub-zero temperatures with an increase in sheet thickness (the affect appears to be most noticeable between 0.032" and 0.060"). Therefore, it is recommended that EXF 301 stainless steel sheet of thicknesses greater than 0.030 to 0.040 inches not be used for structural application at extreme sub-zero temperatures (particularly at liquid hydrogen temperatures). Types 304L or 310 stainless steels are recommended for these applications. There appears to be little or no effect of sheet thickness on tensile strength, weld tensile strength or joint efficiency.

TABLE I

Chemical Analysis and History of Materials

Material	301 CRES 60-percent Cold Rolled	301 CRES 60-percent Cold Rolled	301 CRES 60-percent Cold Rolled	301 CRES 60-percent Cold Rolled	301 CRES 60-percent Cold-Rolled	301 CRES 60-percent Cold Rolled
Supplier	Washington	Washington	Washington	Republic	Republic	Republic
Gauge, in.	.023	.032	.013	.060	.080	.100
Heat No.	48112	56760	48175	49681	49681	49681
Coil No.	36125	40151	38358	325B367	325367	325B368
<u>Content, wt. %</u>						
Cr	17.64	17.64	17.02	17.34	17.34	17.34
Ni	7.11	7.11	7.11	7.10	7.10	7.10
C	.08	.08	.10	.12	.12	.12
Mn	1.04	1.04	.61	1.12	1.12	1.12
P	.028	.028	.026	.018	.018	.018
S	.014	.014	.017	.010	.010	.010
Si	.64	.64	.55	.36	.36	.36
N	-	-	-	.024	.024	.024

TABLE II

Rollarc Butt Weld Schedules*

MATERIAL	GAUGE	AMPS	VOLTS	SPEED	BACKUP GAS	TORCH GAS	CLAMP PRESSURE	BACKUP BAR PRESSURE	ROLL PLANISH		
									psi	in	No.
CRES	in.		dcsp**	in./min	cfh/	cfh/	psi				
301, 60% C.R.	.013	8	8 1/2	10	A/9	A/9	40	Stain- less steel	45	.25	2
"	.023	14	14	12	A/9	A/He:2/45	40	"	50	.25	2
"	.032	16	15	15	A/11	A/He:2/45	40	"	55	.25	2
"	.060	30	15	7	A/16	A/He:2/45	40	"	65	.25	2
"	.080	35	14	8	A/15	A/He:3/40	40	"	65	.25	2
"	.100	38	15	6	A/15	A/He:3/40	40	"	65	.25	2

*No welding wire used in any weld
**Direct current, straight polarity
#Cubic feet per hour

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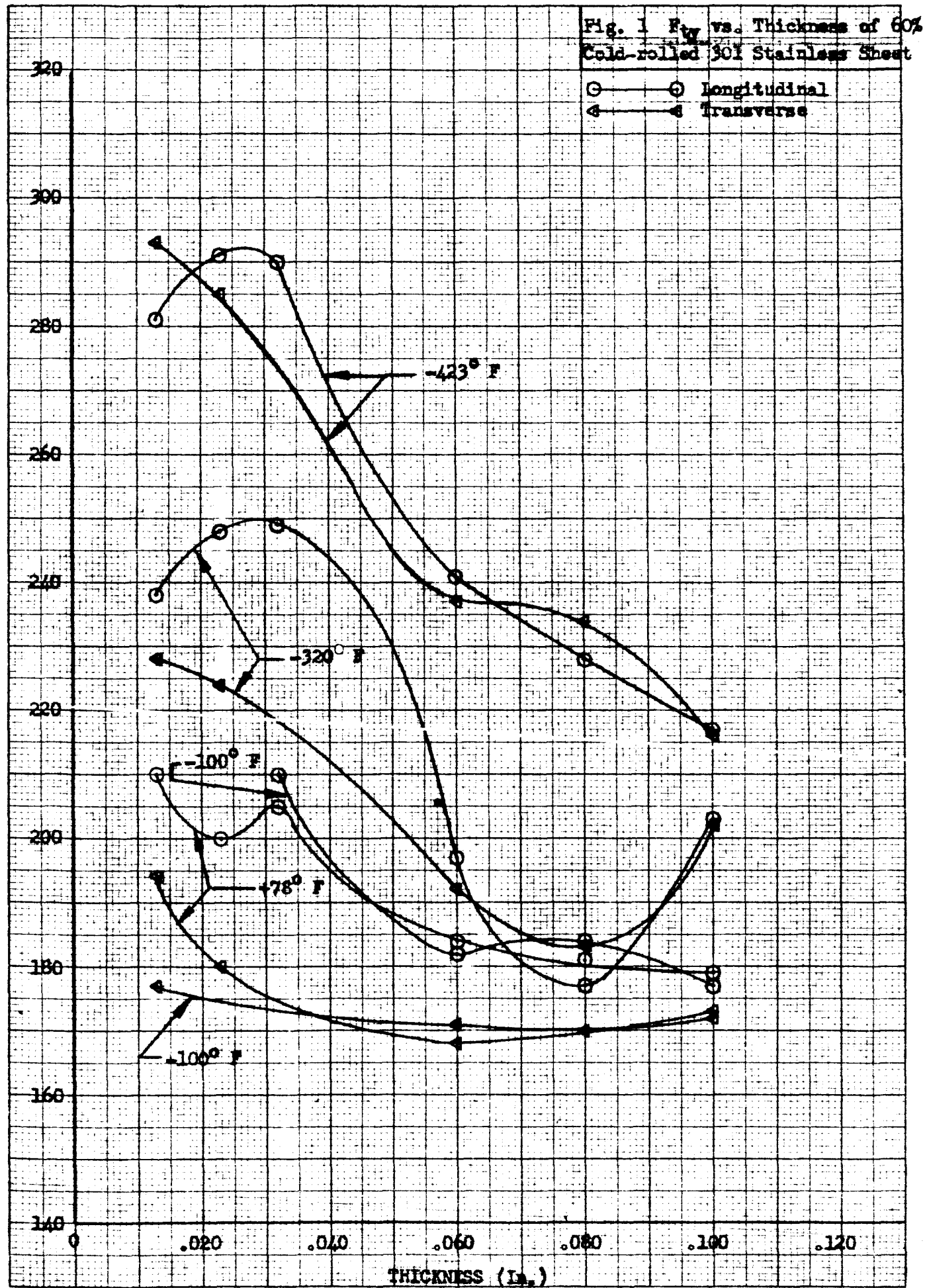


Fig. 2 F_{tu} vs. thickness of 60%
Cold-rolled 301 Stainless Steel Sheet

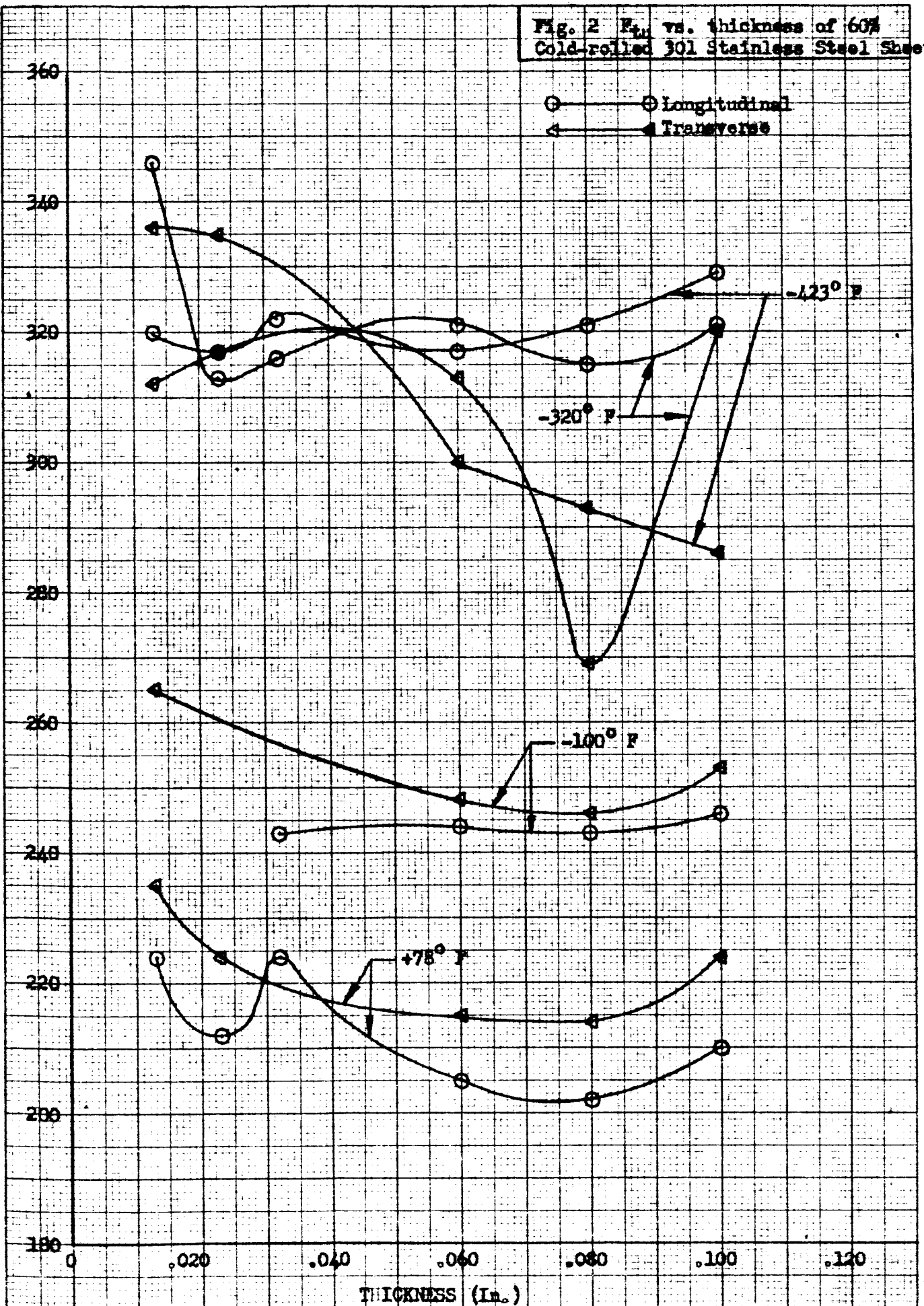


Fig. 3 Percentage of Elongation of
60% Cold-rolled 301 Stainless Steel
Sheet vs. Thickness

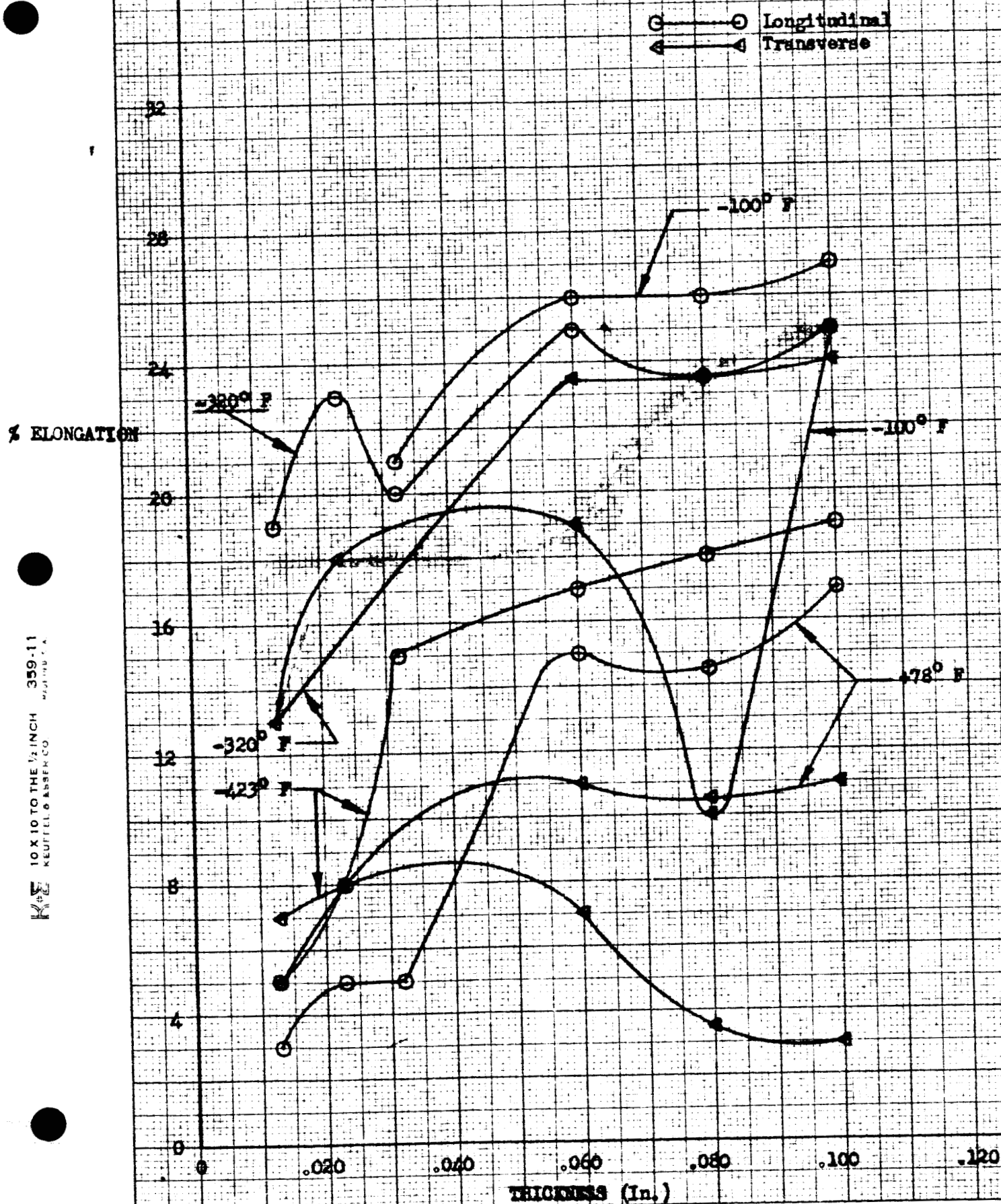


Fig. 4 Notched Tensile Strength vs. Thickness of 60% Cold-rolled 301 Stainless Steel Sheet.

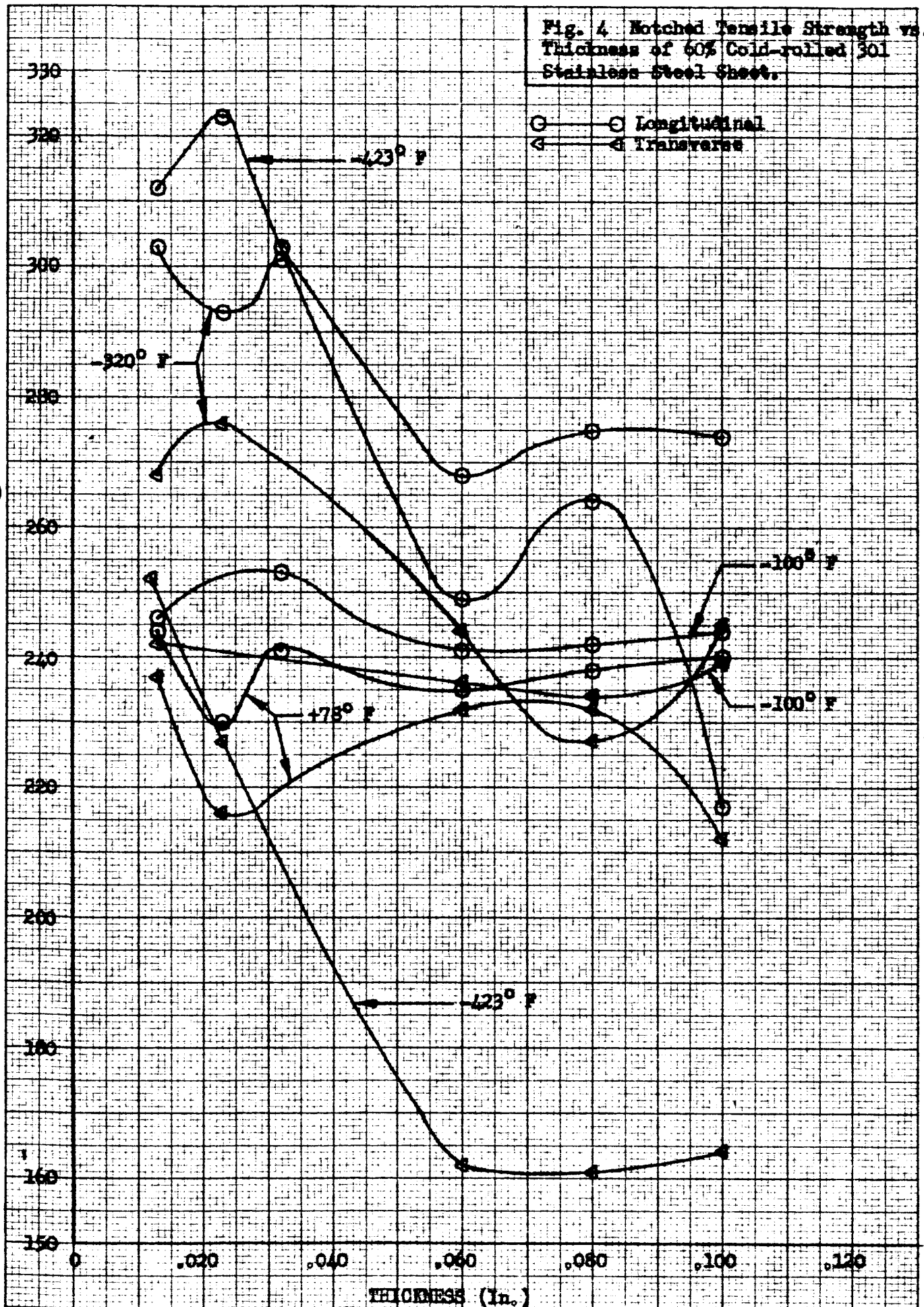
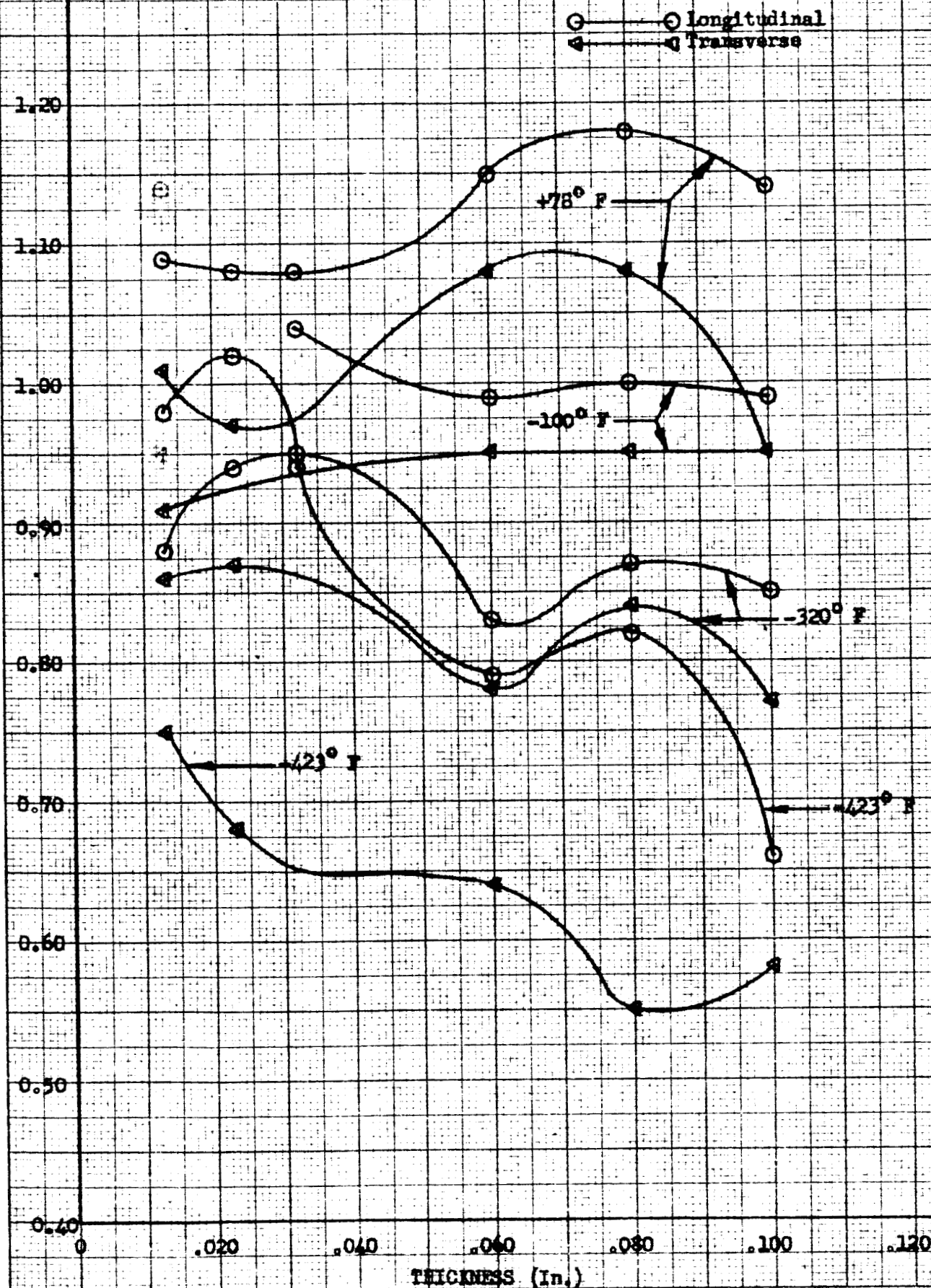
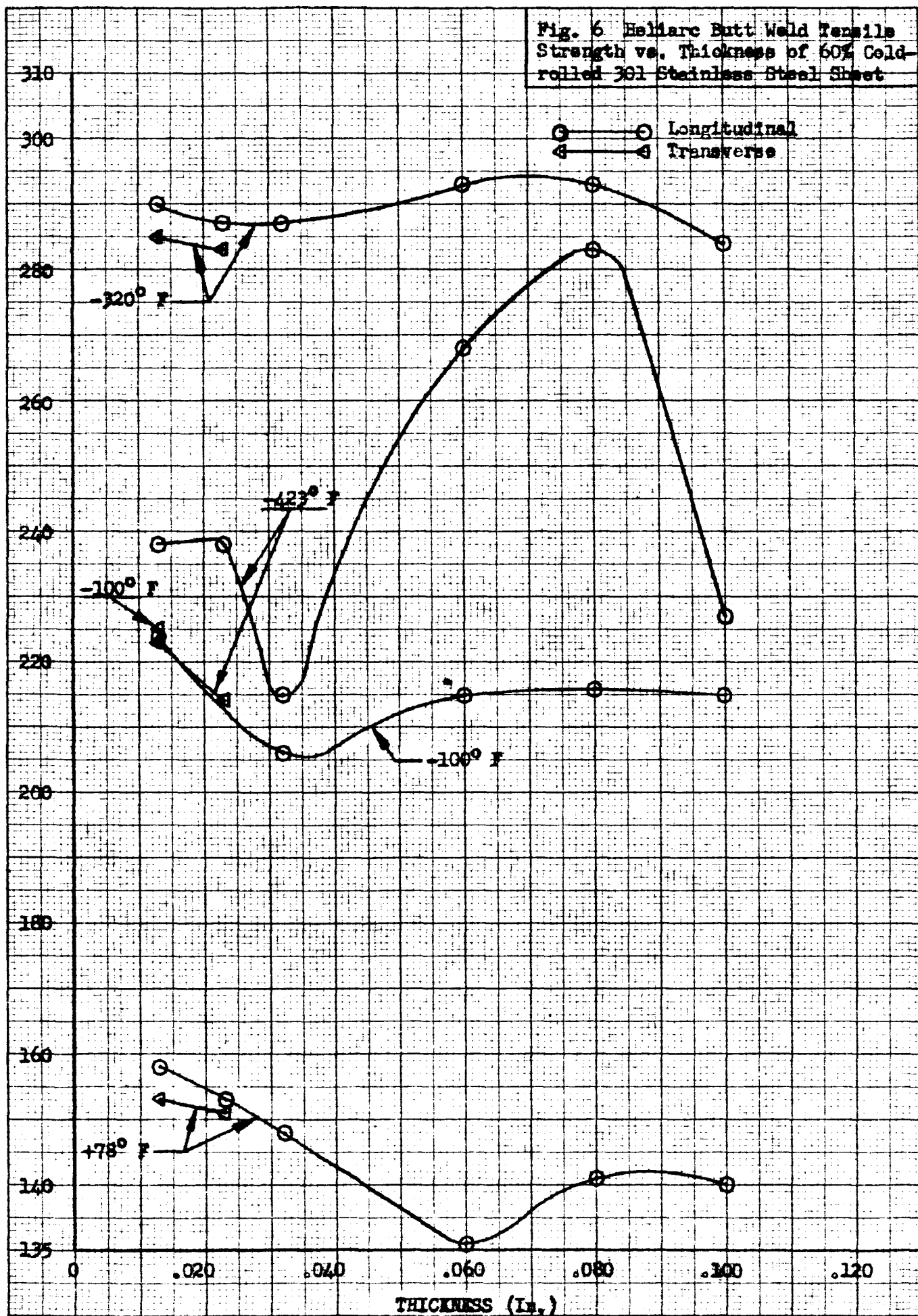


Fig. 5 Notched/Unnotched Tensile Ratio vs. Thickness of 301 60% Cold-rolled Stainless Steel



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Fig. 6 Helmarc Butt Weld Tensile Strength vs. Thickness of 60% Cold-rolled 301 Stainless Steel Sheet



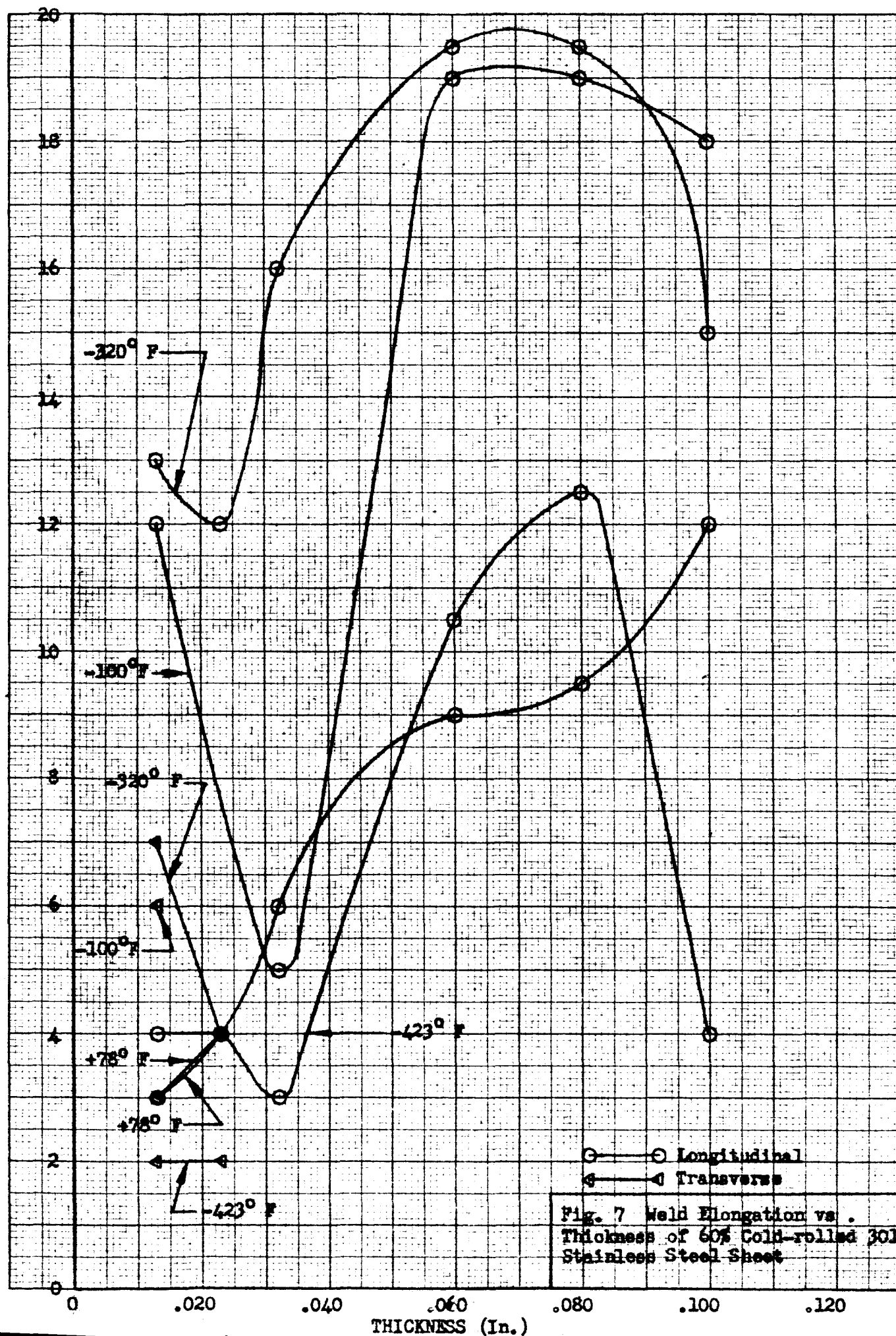


Fig. 7 Weld Elongation vs. Thickness of 60% Cold-rolled 301 Stainless Steel Sheet

Fig. 8 Joint Efficiency vs. Thickness of 60% Cold-rolled Stainless Steel Sheet

